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PREFACE

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Special issue "Studies on electromagnetic induction in the earth: recent advances"

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Research into electromagnetic induction of the Earth's and planetary interiors has increased considerably within the last decade. The 23rd Electromagnetic Induction Workshop (EMIW) held in Chiang Mai, Thailand, in August 2016 was a premier event for the international research community to exchange the latest developments in the field of electromagnetic induction. This special issue is intended to promote the activity of this vibrant and growing research community and to foster future interdisciplinary studies within the broader earth and planetary sciences. It is a compilation of 10 papers consisting of full research papers, letters, express letters, and a technical report on various topics ranging from terrestrial to marine, from instrumentation to inversion, and to interpretation.

1. Electromagnetic modeling

Most of the inversion techniques for magnetotelluric measurement often yield smooth structures. This makes it difficult to locate the interface boundary between resistivity contrasts. In "Regularized magnetotelluric inversion based on a minimum support gradient stabilizing function," Xiang et al. (2017) proposed a new MSG stabilizing function for imaging sharp interfaces for 1-D and 2-D MT inversion. By performing tests on synthetic data, they found that the new technique yields overall good performance in both data fitting and model recovery, and particularly in resolving geoelectrical interfaces. This suggests that the new technique will be useful for practical applications.

2. Engineering applications

Limitations such as highly resistive terrains, coils that are too long to fit in a narrow tunnel space, and the absence of a GPS signal make it difficult to use conventional surface EM receivers to measure the signal inside tunnels. In their work "Electromagnetic receiver with capacitive electrodes and triaxial induction coil for tunnel exploration," Kai et al. (2017) introduced capacitive electrodes and triaxial induction coils that help avoid these limitations. They successfully developed their new design, and their tests in a mine showed that the new equipment can be used to measure EM signals inside tunnels with typical noise characteristics.

Monitoring of hydraulic fracturing fluids is important for geothermal exploration. This can be conducted using many different methods. In their paper "Monitoring hydraulic stimulation using telluric sounding," Rees et al. (2018) found that a telluric sounding (TS) method is relatively cheap and easy to operate for monitoring hydraulic fracturing at depth compared to full magnetotelluric measurement. In the synthetic studies, consistent changes of the transfer function could be observed to be associated with the fluid movement. However, for the real data test from the Paralana geothermal system, South Australia, due to the high noise level, high-quality electric field data from a controlled source may be necessary.

3. Tectonic studies

As the electrical resistivity values of rocks of the crust and upper mantle are quite sensitive to the presence aqueous fluids and partial melts, MT plays a major role in these scenarios. In their research paper "Regional electrical structure of the Andean subduction zone in

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central Chile (35°–36°S) using magnetotellurics," Reyes-Wagner et al. (2017) used broadband MT data acquired in the Southern Volcanic Zone of the Andes to map the subduction zone and establish its relation with the volcanic arc at 35°–36°S latitude. Their final resistivity model brought out the resistive nature of the forearc structure and also a wide region of high conductivity extending from the volcanic front to the east indicating the highly active magmatism of the region.

The geodynamics of the Cambay Rift Zone, India, is quite complex. Danda et al. (2017) conducted a broadband and long-period MT profile with a length of 200 km in the area and processed the result to yield a 2-D resistivity model in their work "Geoelectric structure of northern Cambay rift basin from magnetotelluric data." They interpreted the high-conductivity zones as fluid emplacement in the west and the presence of fluids and/or interconnected sulfides in the east. In addition, a highly resistive body outside of the rift zone was interpreted as an igneous granitic intrusive complex.

Tracing the Indian crustal front beneath Tibet remains a controversial issue. In their paper "Varying Indian crustal front in the southern Tibetan Plateau as revealed by magnetotelluric data," Xie et al. (2017) used previous MT data to generate a 3-D geoelectrical model in southern Tibet to cope with the Indian crustal front. They found conductive layers beneath the mid- to lower crust, suggesting that the Indian crustal front varies irregularly from west to east. This observation was also supported by seismic results.

Understanding the locked fault is very important because locked zones can potentially generate a large earthquake in the future. Karaş et al. (2017) used MT data to produce a general 3-D resistivity model in their research paper "Electrical conductivity of a locked fault: investigation of the Ganos segment of the North Anatolian Fault (NAF) using three-dimensional magnetotellurics." The geoelectric model brought out the fault zone conductor (FZC) corresponding to the Ganos Fault, ophiolitic basement, and Kesan Formation. A distributed conduit behavior of fluid flow in the vicinity of the Ganos Fault was interpreted. The absence of any fluid pathway at greater depths and the mechanically strong and resistive media on both sides of the fault suggest a locked nature of the Ganos Fault.

4. Geomagnetic studies

Prior to the establishment of a new geomagnetic observatory, Padilha et al. (2017) presented a research letter titled "Effect of a huge crustal conductive anomaly on the H component of geomagnetic variations recorded in central South America." The authors reported anomalous amplification of the H component of the geomagnetic field that was recorded in the central-west region of Brazil. The anomalous behavior of the geomagnetic variations is due to the presence of a 1200-km-long conductor and was explained on the basis of classical electrodynamics as the reflection of EM waves at this interface with a very good conductor and the damping of the EM wave amplitude by the skin effect during its propagation through the conductive medium. The authors proposed that a detailed MT survey be carried out prior to the establishment of the new geomagnetic observatory to evaluate the influence of induced currents on the geomagnetic field.

5. Marine EM studies

In contrast to the MT data, which show no evidence of electrical anisotropy, recent seismic data from the NoMelt experiment presented a strong anisotropy in the upper mantle. Matsuno and Evans (2017) revisited the MT data to answer the question of whether electrical anisotropy really existed in the data in their express letter "Constraints on lithospheric mantle and crustal anisotropy in the NoMelt area from an analysis of long-period seafloor magnetotelluric data." Interestingly, they found that electrical anisotropy is possible at lower lithosphere depths. However, this is not related to the anisotropy found in the seismic data at upper and mid-lithosphere depths. Seismic anisotropy at this depth is not expected to generate measurable MT data.

To study the nature of old oceanic upper mantle, Baba et al. (2017) analyzed many seafloor MT data in the northwestern Pacific in their full research paper "Electrical conductivity of old oceanic mantle in the northwestern Pacific I: 1-D profiles suggesting differences in thermal structure not predictable from a plate cooling model." Significant differences in resistive layer thickness were observed between the four zones of investigation, and these could not be explained by only a plate cooling model. The authors suggested that these differences may have been caused by the influence of the plume associated with the formation of the Shatsky Rise or by spatially non-uniform and small-scale convection in the asthenosphere.

Authors' contributions
All authors of this article served as guest editors for this special issue. All authors read and approved the final manuscript.

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